Power Spectral Analysis in Anterior Temporal and Masseter Muscles at Sustained Submaximal Isometric Contraction close to Chewing Force Level

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I. INTRODUCTION

A common complaint of patients with functional disturbances of the masticatory system is muscle pain. Hyperactivity of masticatory muscles and the consequent muscle fatigue are major causes for pain in masticatory muscles in myofascial pain dysfunction(MPD)[1]. Studies on the influences of hyperactivity on the jaw closing musculature have shown that there were great variations both in the susceptibility of muscles to fatigue[2,3]. And extensive researches have been performed on the EMG and force characteristics of the jaw closing motor system. The jaw closing motor system has been studied for its endurance, fatigue, and recovery characteristics[4-9]. However, little information is available regarding the endurance, fatigue, and recovery characteristics of the jaw closing musculature.

Neuromuscular fatigue has been defined as a reduction in the capacity of neuromuscular system to generate force or to perform work[10]. Neuromuscular fatigue can be measured by the presence and absence of force decay and a comparing muscle force output and EMG activity during a sustained contraction[9]. Another method of demonstrating neuromuscular fatigue is to evaluate the EMG signals for any shift in the EMG frequency spectrum.

EMG can be analysed quantitatively in the time or frequency domain. Both systems have been used to investigate the characteristics of neuromuscular system. In the last decade, more attention has been focused on frequency analysis, because it offered a method of studying the motor unit action potentials

(MUAPs) in the EMG signals, even when these were obtained at high contraction levels and the individual motor unit action potentials were buried in the interference pattern[11]. Frequency analysis is carried out by a digital computer using a fast Fourier transform(FFT) algorithm to generate the power spectral density function and the power spectra of signals[12].

Frequency analyses have been used in many studies to investigate the muscle fatigue[13-20]. Several studies examined changes in EMG frequency spectrum of the jaw closing muscle during a fatigue task[3,18,21]. These have all demonstrated a progressive shift of the mean power frequency to a lower frequency level during a sustained isometric contraction. It has been suggested that the shift was clear evidence of neuromuscular fatigue. However, the specific electrophysical changes in the neuromotor system that are responsible for the shift are still the subject of debate. Nevertheless, frequency analysis is sensitive to the changes in EMG frequency characteristics which occur during a sustained isometric contraction.

Studies on the comparison of frequency analysis between controls and patients with muscular pain and dysfunction have been performed[14,20,22-24]. Some studies[20,22,23] reported that there were significant differences between control and patient groups, but other studies[14,24] presented opposite results. Clark et al.[22] reported that the MPD subjects had a lower maximum voluntary bite force level and a shorter endurance time when compared to normal subjects. And Kim and Lee[20] found that the slope of median frequency of patients with masticatory muscle tenderness was lower than that of normal subjects in anterior temporal and masseter muscles. However, Naeije and Hansson failed to find differences in mean power frequency among their myogenous, arthrogenous, and control groups at 50% maximum voluntary contraction(MVC). Similarly, in a study of the power spectra of the temporalis anterior at 50% of MVC, van Boxtel and Goudswaard[14] found no significant differences among controls and migraine headache, muscle contraction headache, and mixed headache patients when comparing the absolute median frequency and the rate of change of median frequency during fatigue.

Frequency analysis may help in understanding muscle dysfunction, even though there has been some debate upon the mechanism of a shift of the mean power frequency and upon the results from studies of comparing patients with controls. However, the majority of studies for muscle fatigue have been investigated the EMG signals at relatively higher contraction level than chewing force level and during relative short time. Especially, little studies on the power spectral analysis at lower isometric contraction close to chewing force level were performed. Therefore, it is necessary to investigate the EMG power spectrum at submaximal isometric contraction close to chewing force level, because chewing is one of important movements of jaw. And frequency analysis at relatively higher contraction level (about 70 to 100% of MVC) have some difficulties on the application to patient in clinic, because patients can not sustain for sufficient time due to muscle pain.

Before this frequency analysis at lower isometric contraction close to chewing force level can be used to study muscle function and dysfunction, it is necessary to define the EMG power spectrum of jaw closing muscles of normal subjects and to investigate what various parameters may affect it.

Our purpose was to investigate the EMG power spectrum in the jaw closing muscles at sustained submaximal isometric contraction level which was close to chewing force level. Specifically, the EMG power spectrum for the anterior temporal and masseter muscles were examined at the beginning and end of sustained efforts.

II. MATERIALS AND METHODS

Subjects

Twenty-five subjects (14 males and 11 females), without functional disturbances or pain in jaw, face, and head and neck, and with natural dentition, aged from 23 to 26 (24.25± 0.74), participated in this study. They were selected from students at the Dental School, Seoul National University.

Reading Apparatus

The computerized EMG system, "SCU-1", was used in the recording and the analysis of the myoelctric signals. This system could calculate automatically the integrated EMG (IEMG), and the median frequency(MF) and the slope of median frequency(SMF) on the power spectrum from recorded myoelectric signals, and displayed the results on the EMG computer monitor.

Recording procedure

The subjects were seated upright on the dental chair with headrest so that Frankfort plane was paralleled to the floor. The myoelectric signals were recorded simultaneously from anterior temporal and masseter muscles on both sides using bipolar Ag-AgCl surface EMG electrodes which were placed according to the positions described by Jankelson and Pully[25].

In order to estimate the maximum voluntary contraction(MVC) level, the subjects were asked to clench three times as hard as passible in maximal intercuspal position and the mean of three values was defined as the maximum voluntary contraction(MVC) level in this study.

The subjects were asked to sustain the isometric contraction at 40% level of MVC with visual biofeedback for 120 seconds, and the author checked the contraction level during isometric contraction task. And recordings were performed in first and last 30 seconds for both anterior temporal and masseter muscles simultaneously.

The analogue myoelectric signals of both anterior temporal and masseter muscles from first and last 30 seconds (beginning and ending periods) during sustained effort were analysed. The obtained analogue myoelectric signals from both beginning and ending periods were rectified and converted into digital signals using a 1024 Hz sampling rate, and filtered with a low pass filter of 512 Hz. The digitalized myoelectric signals were analyzed automatically by an EMG program and the analyzed results were displayed on monitor.

The IEMG, MF and SMF of both anterior temporal and masseter muscles were calculated automatically by an EMG program and displayed on monitor, and the mean median frequency(MMF) were calculated by other program from 30 MFs.

Statistical Analysis

All statistical analyses were performed by SPSS/PC+ (Microsoft Co.). An ANOVA was used to examine the effect of gender and age on the MMF and SMF, and paired T-tests were performed to evaluated the differences

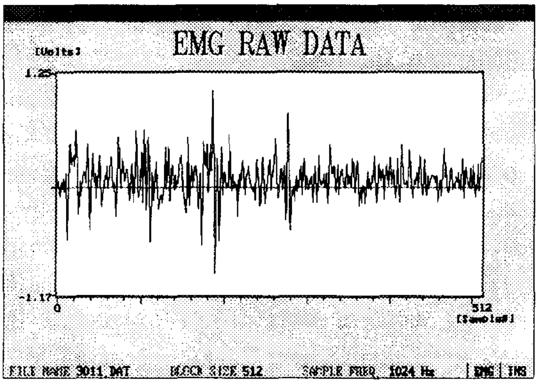

Fig. 1. The EMG raw data was recorded from the left anterior temporal muscles.

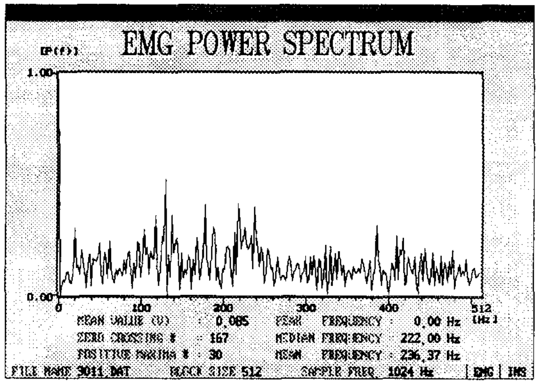

Fig. 2. The EMG power spectrum was recorded from the left anterior temporal muscle.

between the right and left sides and the differences between the beginning and ending periods on the IEMG, MMF and SMF.

Ⅲ. RESULTS

Fig. 1, Fig. 2, and Fig. 3 show the results displayed on the EMG computer monitor for the EMG Raw Data, the EMG Power Spectrum, and the EMG Muscle Fatigue which contained the MF and SMF.

Table 1 shows the results of ANOVA of two independent variables, gender and age, for the beginning and ending periods. Table 1 indicate that the MMF and SMF were not affected by gender and age.

The means and standard deviations of MMF and SMF for anterior temporal and masseter muscles are presented in Table 2. No significant differences were found between the MMF values for the right and left anterior temporal muscles, and there were also no significant differences between the SMF values for the right and left anterior temporal muscles. The same results were found in the masseter muscles.

The MMF and SMF for each period are given in Table 3. There were significant decreases in the MMF between the beginning and ending periods for the anterior temporal and masseter muscles. And there were no significnat differences in the SMF between the beginning and ending periods for the anterior temporal and masseter muscles.

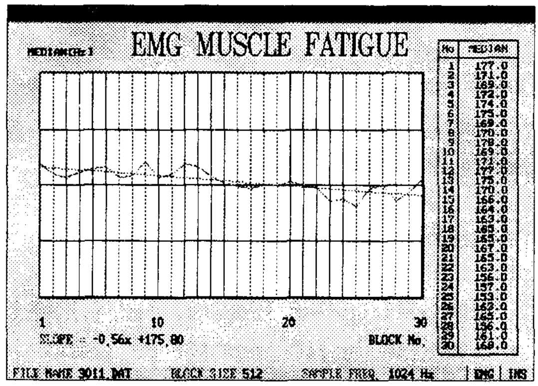

Fig. 3. The change of median frequency for 30 seconds in the left anterior temporal muscle.
The MMF was calculated from thirty median frequencies of right side table, and the SMF was calculated by linear regression analysis.

Table 1. Statistical Analysis of Variancies

	Anterior Temporal Muscle				Masseter Muscle			
	Left		Right		Left		Right	
<u>Beginning Period</u>								
for MMF								
SEX	F=0.096	P=0.761	F=3.236	P=0.090	F=3.136	P=0.096	F=0.098	P=0.758
AGE	F=1.210	P=0.321	F=2.064	P=0.158	F=1.841	P=0.191	F=0.527	P=0.599
for SMF								
SEX	F=0.063	P=0.806	F=2.317	P=0.148	F=0.208	P=0.655	F=0.005	P=0.946
AGE	F=2.654	P=0.103	F=1.881	P=0.185	F=0.349	P=0.711	F=0.149	P=0.863
<u>Ending Period</u>								
for MMF								
SEX	F=0.421	P=0.524	F=2.358	P=0.143	F=0.669	P=0.428	F=0.134	P=0.719
AGE	F=0.644	P=0.537	F=0.610	P=0.555	F=0.538	P=0.596	F=0.156	P=0.857
for SMF								
SEX	F=0.861	P=0.369	F=9.092	P=0.108	F=0.126	P=0.730	F=0.074	P=0.789
AGE	F=2.244	P=0.143	F=0.442	P=0.651	F=0.713	P=0.513	F=0.365	P=0.700

MMF : Mean Median Frequencies
SMF : Slope of Median Frequencies

Table 2. Side Differences of MMF and SMF at the beginning and ending periods

		Left		Right		Sig.
		Mean	S.D.	Mean	S.D.	
<u>Ant. Temporal Muscle</u>						
Beginning Period	MMF	181.72	35.65	176.17	26.46	N.S.
	SMF	-0.04	0.20	-0.09	0.27	N.S.
Ending Period	MMF	167.61	37.14	161.78	24.50	N.S
	SMF	-0.34	0.68	-0.29	0.46	N.S
<u>Masster Muscle</u>						
Beginning Period	MMF	174.82	23.59	172.67	26.49	N.S
	SMF	-0.13	0.21	-0.21	0.25	N.S
Ending Period	MMF	161.10	21.72	160.99	23.05	N.S
	SMF	-0.18	0.40	-0.13	0.25	N.S

N.S.: p>0.05

MMF : Mean Median Frequencies
SMF : Slope of Median Frequencies

Table 3. Means and S.D. of MMF and SMF at the beginning and ending periods

	IEMG		MMF		SMF	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Ant. Temporal Muscle						
Beginning Period	181.35	64.20	176.12	28.17	-0.10	0.16
Ending Period	168.32	79.53	164.69	28.25	-0.31	0.57
Sig.	N.S.		**		N.S.	
Masseter Muscle						
Beginning Period	208.77	52.48	173.74	23.46	-0.17	0.16
Ending Period	209.93	61.02	161.05	20.59	-0.16	0.28
Sig.	N.S.		**		N.S.	

N.S.: $p>0.05$
** : $p<0.01$

IEMG : Integrated EMG
MMF : Mean of Median Frequencies
SMF : Slope of Median Frequencies

Ⅳ. DISCUSSION

In early EMG analysis, the electric activity of a muscle is generally quantified as the root-mean-square, or in terms of integrated values in the time domain. These integrated values have been shown to have a linear relation with the force produced in muscles with predominantly uniform fiber composition, and to have a non-linear relation with the force in muscles with mixed fiber composition[26]. With the development of signal acquisition and analysis technique, some attention has been focused on the frequency domain, because it offers a method of studying the motor unit action potentials(MUAPs) in the EMG signals[27]. Thus, the frequency analysis gives additional informations on the condition of the muscle than the amount of muscle contraction. In recent studies for the fatigue of muscle, the time domained interfered myoelectric signals have been reformed into frequency domained signals by FFT.

Some frequency parameters have been suggested to present the changes in the power spectral density. The mean frequency and the median frequency were considered to be reliable, but Stulen and De Luca[28] suggested that the median frequency was less sensitive to noise than the mean frequency. Therefore, in this study, the SMF, which was calculated with linear regression analysis of 30 median frequencies, and the MMF, which calculated with 30 median frequencies, were used as a parameter to evaluate the change of EMG power spectrum.

In this study, to evaluate the characteristics of EMG power spectrum at the physiologic chewing force level, the author asked subjects to sustain the isometric contraction at 40% level of MVC, which was similar level to the investigations of Gibbs et al. and Lee and Kim. Gibbs et al.[29] reported that the chewing force was 36.2% of maximal biting force, and Lee and Kim[30] reported the EMG activities of chewing were 38.09% in the anterior temporal muscle and 29.53% in the masseter muscle. There were various variations of another experimental conditions, such as the sustained time or the endurance time. Naeije and Zorn[2] reported that the time the subjects could sustain the contraction at 50% of the maximum EMG activity varied from 40 to 120 seconds with a mean value of 98 seconds. Clark et al.[7] found that the mean time required for the subjects to reach the limit of endurance (pain tolerence) at 30% maximum voluntary bite force(MVBF) was 176.8 seconds, and Clark and Carter[8] found that the average endurance times were 287 and 115 seconds for force levels of 25 and 50%. So the author asked to sustain at 40% level of MVC for 120 seconds

As many studies suggested that the anterior temporal muscle had some different characteristics from the masseter muscle, it might be more appropriate to perform frequency analysis of muscles independently. The difference in the frequency spectrum of each masticatory muscle may be due, in part, to the proximity of the muscle fibers to the skin surface, because the connective tissue and fat act as low-pass filter[31]. The fact that it is nearer to the surface may be one reason the high-frequency component are relatively stronger in the anterior temporal power spectrum than in the masseter[18]. Furthermore, many recent studies have indicated that there might be relationship between the muscle fiber types and the mean frequency of its power spectrum[32-35], and the difference of fiber type between temporalis and masseter muscle was reported[36]. And the difference of MMF between the anterior temporal and masseter muscles also was reported[13,18,27,30,37].

As expected, the IEMG of anterior temporal and masseter muscles in this study had no significant difference between the beginning and ending periods (Table 3). This result may reflect that subjects sustained very well at 40% level of MVC during isometric contraction and is consistent with other investigations. Clark and Carter[8] demonstrated that the temporal and masseter muscles did not show the decay in their intermittent brief maximum voluntary contraction ability when sampled during a sustained isometric task. But, this pattern of unchanging MVC ability was distinctly different from the progressive decay in MVC ability of the hand-grip muscles under similar isometric contraction[38].

This study shows that the gender and age did not affected the values of the MMF and SMF of anterior temporal and masseter muscles at the beginning and ending periods. This results is not identical to Yuen's study[27], and it may be explained by the characteristics of subjects, statistical methods performed, and parameters used. In this study, the age range of subjects was much narrower than that of Yuen's study, because subjects were selected from dental school students (minimum 23 years, maximun 26 years). Furthermore, this study used the median frequency as a parameter, but Yuen's study used the mean frequency. And differences in electrode type, size, and position might account for this difference, also. Although the author suggested some factors to explain the different results from Yeun's study, there remains much to debate. Further studies such as a histochemical techniques are needed to confirm the variable results in the difference between male and female and the difference according to age.

There were also no differences in the MMF and SMF values at the beginning and ending periods between anterior temporal muscles of opposite sides, and between masseter muscles of opposite sides. These finding agree with those of Naejie and Zorn[2], Kim and Lee[20], Lee and Kim[30], and Duxbury et al.[39]. It seems to be natural because the identical muscle on contralateral side has the same characteristics and location and because myoelectric signal recordings were performed simultaneously and electrode positions were similar.

The progressive shift, the author found in this study, for the power spectrum of EMG signals of anterior temporal and masseter muscles toward lower frequencies due to the fatiguing process is in agreement with the findings by Palla and Ash[40] and Hellsing and Lindström[41]. This shift is the result of the reduction of the high frequency components of the power spectrum and the increase of the lower frequency components.

The shift in the EMG power spectrum, due to fatigue, were often attributed to a decrease in conduction velocity of the action potentials along the muscle fibers[42,43]. And this decrease in conduction velocity is related to an accumulation of metabolic by-products(lactic acid) of the anaerobic metabolism in the muscle due to a (partial) obstruction of the blood flow to the muscle during the contraction. But, other investigators cast doubt on the dominant role of the conduction velocity changes. Other mechanisms possibly responsible for the EMG power spectrum change during muscle fatigue were an increasing synchronization between the motor units[18,44] and, at submaximal contraction, the continuous recruitment of larger motor units to compensate for the fatigued ones[18,45].

In this study, comparisons of EMG frequency spectrum data of the beginning and ending periods showed a clear and consistent decrease in the mean median frequency with a sustained isometric contraction and showed that the rate of frequency shift, characterized by the slope of median frequency(SMF), have no increase or decrease during a sustained effort. It indicates that the shift of EMG power spectrum to lower frequency level during a sustained isometric contraction at a chewing force level, about 40% of MVC, is clear and that the ratio of frequency shift may have no significant change during a sustained isometric contraction, at this contraction level. And the MMF and SMF is useful as parameter to evaluated the muscle fatigue with sustained isometric contraction at a chewing force level and may be applicable to patients with muscular pain and/or dysfunction.

Futher studies should be performed whether the progessive shift of MMF is present and whether the SMF has no significant change at other levels of fatiguing effort. And a study to compare patients with normal subject are needed also.

V. CONCLUSIONS

Hyperactivity of the masticatoy muscles and the consequent muscle fatigue are major causes for pain in masticatory muscles in myofascial pain dysfunction(MPD). Neuro-muscular fatigue has been defined as a reduction in the capacity of neuromuscular system to generate force or to perform work.

EMG can be investigate the characteristics of neuromuscular system quantitatively in the time or frequency domain. Especially, a method of demonstrating neuromuscular fatigue is to evaluate the EMG signal for any shift in the EMG frequency spectrum.

To study the characteristics of EMG power spectrum in the jaw closing muscles at sustained submaximal isometric contraction close to chewing force level, the author analysed the EMG signals of anterior temporal and masseter muscles at 40% level of maximum voluntary contraction(MVC) for 120 seconds. Specifically, the EMG power spectrum(characterized by SMF and MMF) for the anterior temporal and masseter muscles were examined at the beginning and end of sustained efforts.

Twenty-five normal subjects participated in this study.

The obtained results were as follows :

1. The mean median frequencies(MMFs) and the slope of median frequencies(SMFs) of anterior temporal and masseter muscles at sustained submaximal isometric contraction close to chewing force level were not affected by gender and age.
2. The mean median frequencies(MMFs) and the slope of median frequencies(SMFs) of anterior temporal and masseter muscles did not show any differences between right and left sides.
3. The mean median frequencies(MMFs) for anterior temporal($p<0.01$) and masseter ($p<0.01$) muscles of ending period were lower than those of beginning period.
4. With sustained isometric contraction, the power spectrum of anterior temporal and masseter muscles during both beginning and ending periods shifted to lower frequency level, and the slope of median frequencies(SMFs) showed no significant differences between beginning and ending periods in both muscles.

REFERENCES

1. Laskin D.: Etiology of the pain dysfunction syndrome. J.Am.Dent.Ass.79, 147-153, 1969.
2. Naeije M. and Zorn H.: Changes in the power spectrum of the surface electromyogram of human masseter muscle due to local muscular fatigue. Archs Oral Biol.26, 409-412, 1981.
3. Naije M.: Correlation between surface electromyograms and the susceptibility to fatigue of human masseter muscle. Archs Oral Biol.29, 865-870, 1984.
4. Steenberghe D.van, De Vries H and Hollander A.R.: Resistance of jaw muscles to fatigue during repetitive maximal voluntary clenching efforts in man. Archs Oral Biol.23, 697-701, 1978.
5. Clark G.T. and Beemsterboer P.L.: The effect of sustained submaximal clenching on maximum voluntary bite force. J.Dent.Res.60. 598, 1981.
6. Clark G.T. and Carter M.C.: Jaw closing muscle endurance at various isometric force levels. J.Dent.Rec.61, 324, 1982.
7. Clark G.T., Beemsterboer P.L. and Jacobson R.: The effect of sustained submaximal clenching on maximal voluntary bite force in myofascial pain dysfunction patients. J.Oral Rehab.11, 387-391, 1984
8. Clark G.T. and Carter M.C.: Electromyographic study of human and recovery at various isometric force levels. Archs Oral Biol.30, 563-569, 1985.
9. Clark G.T., Carter M.C. and Beemsterboer P.L.: Analysis of electromyographic signals in human jaw closing muscles at various isomeric force levels. Archs Oral Biol.33,833-837, 1988.
10. Bigland-Ritchie B.: EMG/force relations and fatigue of human voluntary contractions. Exer.Sports Sci.Rev.9, 75-117, 1981.
11. Lindström L., Magnusson R., and Peterson I.: Muscular fatigue and action potential conduction velocity changes studied with frequency analysis of EMG signals. Electromyography 4, 341-356, 1970.
12. Cenkovichi F.S. and Gersten J.W.: Fourier analysis of the normal human electromyogram. Am.J. Phys.Med.42, 192-204, 1963.
13. Van Boxtel A., Goudswaard P., Molen G.M., and Bosch W.E.J.: Changes in electromyogram power spectra of facial and jaw-elevator muscles during fatigue. J.Appl.Physiol. 54, 51-57, 1983.
14. Van Boxtel A. and Goudwaard P.: Changes in EMG power spectra during fatigue in muscle contraction and migraine headache patients. Headache 23, 223-228, 1983.
15. Hanley M.R., Rugh J.D., Dale R.A., and Burgar C.G.:

Time compression spectral analysis of EMG of fatigued masseter muscle. J.Dent.Res.61, Abst.#706, 257, 1982.
16. Kroon G.W., Naeije M., and Hansson T.L.: Electromyographic power spectrum changes during human masseter muscle fatigue. J.Dent.Res.64, Abst.#1148, 302, 1985.
17. Lacouture C.F., Jones D.L., and Blanton L.: Power spectrum analysis of human masticatory muscles during fatigue. J.Dent.Res.64, Abst.#1149, 302, 1985.
18. Palla S. and Ash M.M.: Power spectral analysis of the surface electromyogram of human jaw muscles during fatigue. Archs Oral Biol.26, 547-553, 1981.
19. Sims D.B. and Rugh J.D.: Myoelectric power spectrum analysis using surface electrodes; Measurement problems. J.Dent.Res.61, Abst.#705, 257. 1982.
20. Kim Y.J. and Lee S.W.: A study on electromyographic power spectral analysis of masticatory muscles. J.Dent.Coll.SNU.14, 185-201, 1990.
21. Lindström L. and Hellsing G.: Masseter muscle fatigue in man objectively quantified by analysis of myoelectric signals. Archs Oral Biol.28, 297-301, 1983.
22. Clark G.T., Beemsterboer P.L., and Jacobson R.: The effect of sustained submaximal clenching on maximum bite force in myofascial pain dysfunction patients. J.Oral Rehab.11 387-391, 1984.
23. Hagberg C. and Hargberg M.: Surface EMG frequency dependence on force in the masseter and the anterior temporal muscles. Scan.J.Dent.Res.96, 451-456, 1988.
24. Naeije M. and Hansson T.L.: Electromyographic screening of myogenous and arthrogenous TMJ dysfunction patients. J.Oral Rehab.13, 433-441, 1986
25. Jankelson R. and Pully M.L.: EMG in clinical dentistry, 1-14, Myo-tronics Research Inc., Seattle & Washington, 1984.
26. Wood J.J. and Biglands-Ritchie B.: Linear and non-linear surface EMG/force relationships in human muscles, Am.J.Phys.Med.62, 287-299, 1983.
27. Yuen S.H.W., Hwang J.C.C., and Poon P.W.F.: EMG power spectrum patten of anterior temporal and masseter muscles in children and adults, J.Dent.Res.68, 800-804, 1989.
28. Stulen F.B. and De Luca C.J.: Frequency parameter of the myoelectric signals as a measure of muscle conduction velocity, IEEE.Trans.Biomed.Eng BEM. 28, 512-523, 1981.
29. Gibb C.H., Mahan P.E., Lundeen H.C., Brehnan K. Walsh E.K. Sinkewiz S.L., and Ginberg S.B.: Occlusal forces during chewing and swallowing as measured by sound transmission, J.Prosthet. Dent. 46, 443-449, 1981.
30. Lee H.S. and Kim Y.K.: A study on the analysis of myoelectric signals of anterior temporal and masseter muscles at various isometric contraction levels and during chewing, J.Dent.Coll.SNU.17, 237-259, 1993.
31. Schanne F.J. and Chaffin D.B.: The effects of skin resistance and capacitance coupling on EMG amplitude and power spectra, Electromyography 10, 273, 1970.
32. Hkinnen K. and Komi P.V.: Electromyographic and mechanical characteristics of human skeletal muscle during fatigue under voluntary and reflex conditions, Electroceph. Clin. Neurophisiol.55, 436-441, 1983.
33. Barker G.R., Wastell D.G., and Duxbury A.J.: Measurement of mean power frequency in the masseter and anterior temporal muscles, J.Dent. Res.63, Abst.#35, 493, 1984.
34. Wretling M.L., Gerdle B., and Henriksson-Larssen K.: A non-invasive method for determination of fiber type proportion, Acta.Physiol.Scan.131, 627-628, 1987.
35. Westbury J.R. and Shaughnessy T.G.: Associations between spectral representation of the surface electromyogram and fiber type distribution and size in human masseter muscle, Electromyo. Clin. Neurophysiol.27, 427-435, 1979.
36. Christensen L.V.: Some subjective-experimental parameters in experimental tooth clenching in man, J.Oral Rehab.6, 119-136, 1979.
37. Lund J.P. and Widmer C.G.: An evaluation of the use of surface electromyography in the diagnosis, documentation, and treatment of dental patients, J.Craniomandib. Disord. Facial Oral Pain.3, 125-137, 1989.
38. Lind A.R. and Petrofsky J.S.: Amplitude of the surface electromyogram during fatiguing isometric

contractions. Muscle and Nerve 2, 257-264
39. Duxbury A., Hughes D.F., and Clark D.E.: Power spectral distribution of the masseter electromyogram from surface electrodes, J.Oral Rehab.3, 333-339, 1976.
40. Palla S. and Ash M.M. Jr. : Effect of muscle fatigue on the electromyogram, J.Dent.Res. 59, 370, 1980.
41. Hellsing G. and Lindström L.: An electromyographic study on localized masseter muscle fatigue, J.Dent. Res.59, 892, 1980.
42. Lindstrom L., Magnusson R., and Peterson I.: Muscular fatigue and action potential conduction velocity changes studied with frequency analysis of EMG signals, Electromyography 4, 341-356, 1970.
43. Mortimer J.T.M., Magnusson R., and Peterson I.: Conduction velocity in ischemic muscle; effect on EMG frequency spectrum, Am.J.Physiol.219, 1324-1329, 1970.
44. Palla S. and Ash M.M.: Cross-correlation of electromyogram of the masseter during fatigue, J.Dent.Res.65, Abst.#1373, 323, 1984.
45. Maton B.: Human motor unit activity during the onset of muscle fatigue in submaximal isometric contraction, Eur.J.Appl.Physiol.46, 271-281, 1981.

국 문 초 록

저작 수준의 등척성 수축시 전측두근 및 교근의 근전도 스팩트럼 분석에 관한 연구

서울대학교 치과대학 구강내과 · 진단학 교실

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저자는 저작 수준의 등척성 수축시 하악 폐구근에서의 근전도 스펙트럼의 특성을 규명하기 위하여, 정상 성인 25명을 대상으로 최대수의적 수축의 40% 수준으로 근활성을 2분간 유지하게 하고, 이때 전측두근과 교근에서 얻어진 근전기 신호를 컴퓨터를 이용한 근전도 시스템을 이용하여 분석한 결과 다음과 같은 결론을 얻었다.

1. 저작 수준의 등척성 수축 지속시 시작과 마지막 구간 모두에서 전측두근과 교근의 평균중간주파수와 중간주파수 기울기는 성별 및 연령의 영향을 받지 않았다.
2. 저작 수준의 등척성 수축 지속시 시작과 마지막 구간 모두에서 전측두근과 교근의 평균중간주파수와 중간주파수 기울기는 좌우사이에 통계적으로 유의한 차이가 없었다.
3. 저작 수준의 등척성 수축 지속시 전측두근과 교근의 마지막 구간 평균중간주파수는 시작 구간 평균중간주파수보다 통계학적으로 유의하게 낮았다 (전측두근 : $p<0.01$, 교근 : $p<0.01$).
4. 전측두근과 교근에서 저작 수준의 등척성 수축이 지속됨에 따라 시작 구간과 마지막 구간 모두에서 power spectrum은 저주파 영역으로 이동하였으나, 중간주파수 기울기는 시작 구간과 마지막 구간 사이에 통계적으로 유의한 차이가 없었다.